

MITIGATION OF FERRORESONANCE IN POWER TRANSMISSION  
NETWORK BY APPLYING UPFC AND STATCOM

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## ABSTRACT

Ferroresonance phenomenon occurs in electrical circuits which are consisting of magnetizing cores, such as in the transmission and distribution networks with transformers, electrical machines or reactors. Transformers often operate close to the knee point of the magnetizing curve under normal condition. Therefore any sudden change in voltage or current can change the operating point on the magnetizing curve and saturation may result. This phenomenon is reflected in the change of the equivalent nonlinear reactance of the transformer. Now, if the value of the saturated reactance reaches a value such that it causes resonance with the equivalent capacitance of the network, then an over current or over voltage may occur. Transformers, electrical motors, reactors and generators are examples of equipment having magnetizing cores. Ferroresonance may cause melting of the lamination of the transformer or electrical machine which eventually may lead to the failure of the equipment. This type of fault can create long time interruptions. Possible causes of ferroresonance are switching, faults especially single line to ground or double line to ground, lightning, and Ferranti effect. Although some techniques had been applied to mitigate ferroresonance on CVTs, methods to mitigate ferroresonance on power transformers are almost not studied or reported. This report initially introduces the ferroresonance phenomenon, its definition and circumstances where it occurs. The software used for the simulation is then introduced, whereby the modeling work of the components relevant to the present work is discussed. The simulation work then follows, where suitable circuits for ferroresonance simulation were identified, including those for the mitigation techniques, namely the UPFC and STATCOM. The circuits used to represent the network are introduced and the simulation results are presented and discussed. The UPFC in mode-1 and the STATCOM techniques of mitigation had been shown to successfully mitigate the ferroresonance.

## ABSTRAK

Fenomena ferroresonance berlaku dalam litar elektrik yang mengandungi teras pemagnetan, seperti dalam rangkaian penghantaran dan pengagihan yang mempunyai pengubah, mesin elektrik dan reaktor. Pengubah sering beroperasi hampir ke titik lutut lengkung pemagnetan dalam keadaan biasa. Oleh itu, apa-apa perubahan dalam voltan atau arus secara tiba-tiba boleh menukar titik operasi pada lengkung pemagnetan dan ketepuan boleh terhasil. Fenomena ini dapat dilihat dalam perubahan regangan setara tak lurus pengubah. Jika nilai regangan tepu mencapai satu nilai yang menyebabkan resonan dengan kemuatan setara rangkaian, maka voltan atau arus lampau mungkin berlaku. Pengubah, motor elektrik, reaktor dan penjana adalah contoh peralatan yang mempunyai teras pemagnetan. Ferroresonan boleh mengakibatkan peleburan laminasi pengubah atau mesin elektrik, seterusnya boleh memusnahkannya. Kerosakan ini boleh mewujudkan gangguan kuasa untuk masa yang lama. Antara punca kejadian ferroresonan ialah pensuisan, kerosakan terutamanya talian tunggal ke bumi atau talian berkembar ke bumi, kilat, dan kesan Ferranti. Walaupun beberapa teknik digunakan untuk mengurangkan ferroresonan pada CVTs, kaedah untuk mengurangkan ferroresonan pada pengubah kuasa hampir tidak dikaji atau dilaporkan. Laporan ini pada mulanya memperkenalkan fenomena ferroresonan, definisi dan keadaan di mana ia berlaku. Perisian yang digunakan untuk penyelidikan kemudiannya diperkenalkan, di mana kerja-kerja pemodelan komponen-komponen yang berkaitan dengan kerja-kerja ini dibincangkan. Berikutnya, kerja-kerja simulasi dilaksanakan di mana litar yang sesuai untuk ferroresonan dikenalpasti, termasuk teknik pencegahan menggunakan UPFC dan STATCOM. Litar yang digunakan untuk mewakili rangkaian diperkenalkan dan keputusan simulasi dibentangkan dan dibincangkan. Kaedah pencegahan menggunakan UPFC (mod-1) dan STATCOM didapati mampu mencegah ferroresonan dengan baik.

## TABLE OF CONTENTS

<b>CHAPTER</b>	<b>TITLE</b>	<b>PAGE</b>
	<b>DECLARATION</b>	i
	<b>ACKNOWLEDGMENTS</b>	iv
	<b>ABSTRACT</b>	v
	<b>ABSTRAK</b>	vi
	<b>TABLE OF CONTENTS</b>	vii
	<b>LIST OF TABLES</b>	xii
	<b>LIST OF FIGURES</b>	xiv
	<b>LIST OF SYMBOLS</b>	xviii
<b>1</b>	<b>INTRODUCTION</b>	
	1.1 Project Background	1
	1.2 Problem Statement	2
	1.3 Objectives	3
	1.4 Scope of Project	3
<b>2</b>	<b>LITERATURE REVIEW</b>	
	2.1 Introduction	4

2.2	Theoretical Principles of Ferroresonance	5
2.2.1	Resonance	5
2.2.2	Ferroresonance	5
2.2.3	Evolution of Ferroresonant Operation Point	8
2.3	Modeling Iron Core	9
2.3.1	Preisach-Type Hysteretic	10
2.3.2	Jiles–Atherton Model	12
2.3.2	Tellinen’s Scalar Hysteresis	13
2.4	Ferroresonance Modes	16
2.4.1	Fundamental Mode	16
2.4.2	Subharmonic Mode	17
2.4.3	Quasi-periodic Mode	17
2.4.4	Chaotic Mode	17
2.5	Stability Domain for Ferroresonance interval	18
2.6	Phenomena Relative to Ferroresonance	19
2.7	Damping of Ferroresonance	20

### **3 METHODOLOGY**

3.1	ATP Introduction	22
3.1.1	Simulation of Electric Circuits	23
3.2	Background of Unified Power Flow Controller	23
3.3	Operation of a UPFC	26
3.3.1	UPFC Connected at the Sending End	26
3.3.2	UPFC Connected at the Receiving End	27
3.3.3	UPFC Connected at the Midpoint	29
3.4	Analysis of UPFC	30

3.4.1	Operating Constraints	33
3.5	Protection of UPFC	34
3.6	Background of Static Synchronous Compensator	35
3.7	Principle of Operation of STATCOM	36
3.8	Applications of STATCOM	40

## **4 SIMULATION RESULTS**

4.1	Introduction	43
4.2	Voltage waveform	46
4.3	Harmonic analyze	46
4.3.1	Before Switching	47
4.3.2	After Switching	48
4.4	Effect of Different Switching Time on the Ferroresonance	52
4.5	Effect of Coupling Capacitance	54
4.6	Ferroresonance Occurrence duos Change the Coupling Capacitance	62
4.7	UNIFIED POWER FLOW CONTROLLER (UPFC)	65
4.8	UPFC Mode-1	65
4.8.1	Switching time	67
4.8.2	Analyze of Waveform	67
4.8.2.1	Voltage	66
4.8.2.2	Current	68
4.8.2.3	Nonlinear reactor	68
4.8.3	Harmonic Analyze	70
4.8.3.1	With UPFC mode-1	69

4.8.3.2	Without UPFC mode-1	73
4.8.4	Effect of UPFC Mode-1	77
4.9	UPFC in MODE-2	78
4.9.1	Switching time	79
4.9.2	Analyze of Waveform	80
4.9.2.1	Voltage	78
4.9.2.2	Current	79
4.9.2.3	Nonlinear reactor	79
4.9.3	Harmonic Analyze	82
4.9.3.1	With UPFC mode-2	81
4.9.3.2	Without UPFC mode-2	83
4.9.4	Effect of UPFC Mode-2	89
4.10	Static Synchronous Compensator (STATCOM)	90
4.10.1	Switching Time	92
4.10.2	Analyze of Waveform	92
4.10.2.1	Voltage	90
4.10.2.2	Current	91
4.10.2.3	Nonlinear reactor	92
4.10.3	Harmonic Analysis	95
4.10.3.1	With STATCOM	93
4.10.3.2	Without STATCOM	95
4.10.4	Effect of STATCOM	97
4.11	Result Discussion	98
4.11.1	voltages	101
4.11.2	Apparent power	103
4.11.3	Total Harmonic Distortion and Harmonic Analyze	104



4.11.3.1 THD analysis	104
4.11.3.2 1 <sup>st</sup> Harmonic Analysiss	106
4.11.3.3 2 <sup>nd</sup> Harmonic Analysis	108
4.11.3.4 3 <sup>rd</sup> Harmonic Analysis	110
4.11.4 Peak voltage comparison	112

## **5 CONCLUSION**

5.1 General Discussion	114
5.2 Conclusion	116

<b>REFERENCE</b>	117
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## LIST OF TABLES

TABLE NO.	TITLE	PAGE
Table 4.1	Fourier analysis of the Figure 4.3 for interval of 0 to 0.02s	48
Table 4.2	Fourier analysis of the Figure 4.3 for interval of 0.16s to 0.18s	50
Table 4.3	Fourier analysis of the Figure 12 for interval of 0.17s to 0.19s	51
Table 4.4	Fourier analysis of the Figure 4.3 for interval of 0.18 to 0.20s	52
Table 4.5	Compare between Ferroresonance voltage peak duos to change the switching time	54
Table 4.6	Switching time in simulate circuit	67
Table 4.7	Fourier analysis of the Figure 4.23 for interval of 0.20s to 0.22s	70
Table 4.8	Fourier analysis of the Figure 4.23 for interval of 0.20s to 0.22s	71
Table 4.9.	Fourier analysis of the Figure4.23 for interval of 0.22s to 0.24s	72
Table 4.10.	Fourier analysis of the Figure 4.23 for interval of 0.36s to 0.38s	73
Table 4.11.	Fourier analysis of the Figure 4.23 for interval of 0.45s to 0.47s	74
Table 4.12.	Fourier analysis of the Figure 4.23 for interval of 0.47s to 0.49s	75
Table 4.13.	Switching time in simulate circuit	79
Table 4.14.	Fourier analysis of the Figure 4.31 for interval of 0.36s to 0.38s	82
Table 4.15.	Fourier analysis of Figure 4.31 for time interval of 0.38s to 0.40s	83
Table 4.16.	Fourier analysis of Figure 4.31 for time interval of 0.46sto 0.48s	85
Table 4.17.	Fourier analysis of Figure 4.31 for time interval of 0.48s to 0.50s	86

Table 4.18. Fourier analysis of Figure 4.31 for time interval of 0.50s to 0.52s	87
Table 4.19. Switching time in simulate circuit	92
Table 4.20. Fourier analysis of Figure 4.38 for time interval of 0.20s to 0.22s	93
Table 4.21 . Fourier analysis Figure 4.38 for time interval of 0.22s to 0.24s	94
Table 4.22 . Fourier analysis of Figure 4.38 time interval of 0.24s to 0.26s	95
Table 4.23 . Fourier analysis of Figure 4.38 for time interval of 0.36s to 0.38s	96
Table 4.24. Fourier analysis Figure 4.38 for time interval of 0.38s to 0.40s	97
Table 4.25. Yield of Applying FACTS on Ferroresonance	109

## LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
Figure 1.1	Steps of formation Ferroresonance and Coupling Capacitance	2
Figure 2.1	Series Ferroresonance circuit	6
Figure 2.2	Graphical solution of series Ferroresonance circuit	7
Figure 2.3	Evolution of the solution increasing source voltage E	8
Figure 2.4	Evolution of the solution increasing capacitance value	9
Figure 2.5	Periodic ferroresonance conditions	9
Figure 2.6	An iron core inductor	10
Figure 2.7	Ferroresonance circuit with hysteresis core model	15
Figure 2.8	Ferroresonance Modes	18
Figure 3.1	A UPFC schematic	24
Figure 3.2	A two converter IPFC	25
Figure 3.3	A BTB HVDC link	25
Figure 3.4	A SSSC with a power source connected at the sending end	26
Figure 3.5	Equivalent circuit of a UPFC	27
Figure 3.6	A line supplying a load through UPFC	27
Figure 3.7	Two port network representing a UPFC	29

Figure 3.8	Alternative representations for UPFC	29
Figure 3.9	System equivalent circuit	30
Figure 3.10	Feasible regions for $V_L$ or $V_2$	34
Figure 3.11	A synchronous condenser	37
Figure 3.12	A single phase STATCOM	37
Figure 3.13	The waveform of $\mu_{PN}$	38
Figure 3.14	Control characteristics of a STATCOM	40
Figure 4.1	Circuit for simulate Ferroresonance	44
Figure 4.2	Magnetizing Curve of Transformer Core	45
Figure 4.3	Voltage waveform of Quasi-Periodic Ferroresonance	46
Figure 4.4	Harmonic Analysis before Switching for time interval 0 to 0.02 sec	47
Figure 4.5	Harmonic Analysis after Switching	49
Figure 4.6	Switching at Peak	53
Figure 4.7	Switching at Zero crossing	53
Figure 4.8	The currents and voltage are pure sinusoidal waves.	55
Figure 4.9	The waves for coupling Capacitance =1nF	56
Figure 4.10	The waves for coupling Capacitance =0.01uF	57
Figure 4.11	The waves for coupling Capacitance =1uF	57
Figure 4.12	The waves for coupling Capacitance =10uF	58
Figure 4.13	The waves for coupling Capacitance =15uF	58
Figure 4.14	The waves for coupling Capacitance =20 uF	59
Figure 4.15	The waves for coupling Capacitance =25uF	60
Figure 4.16	The waves for coupling Capacitance =30uF	60
Figure 4.17	The waves for coupling Capacitance =40uF	61
Figure 4.18	The waves for coupling Capacitance =80uF	61

Figure 4.19	The waves for coupling Capacitance =1mF	62
Figure 4.20	Ferroresonance Occurrence duos Change the Coupling Capacitance	64
Figure 4.21	Change in Voltage Peak dues Coupling Capacitance	64
Figure 4.22	UPFC related circuit	66
Figure 4.23	Analysis of voltage of Network	68
Figure 4.24	Current of Network	69
Figure 4.25	Nonlinear reactor waveforms	70
Figure 4.26	Voltage analyze of Figure 32 during ferroresonance (0.18s to 0.20s)	71
Figure 4.27	Voltage analysis of Figure4.23 during ferroresonance (0.20s to 0.22s)	73
Figure 4.28	Voltage analysis of Figure 4.23 during ferroresonance (0.22s to 0.24s)	74
Figure 4.29	Effect of UPFC Mode-1 on Ferroresonance	78
Figure 4.30	UPFC in Mode-2	79
Figure 4.31	Voltage Analysis for UPFC Mode-2	80
Figure 4.32	Current Waveform of UPFC Mode-2	81
Figure 4.33	Analysis of Nonlinear Reactor Waveform	82
Figure 4.34	Harmonic analysis of Figure 4.31 for time interval 0.36s to 0.38s	83
Figure 4.35	Harmonic analysis of Figure 4.31 for time interval 0.46s to 0.48s	86
Figure 4.36	Effect of UPFC Mode-2 on Ferroresonance	90
Figure 4.37	STATCOM related circuit	91
Figure 4.38	Voltage Waveform of STATCOM	93
Figure 4.39	Current Waveform of STATCOM	93
Figure 4.40	Analyze of nonlinear reactor waveform	94

Figure 4.41	Effect of STATCOM	101
Figure 4.42	Compare between voltages	102
Figure 4.43	Apparent power	103
Figure 4.44	Compare THD of FACTS devices and Ferroresonance while FACTS are Switch on	104
Figure 4.45	Compare THD of FACTS devices and Ferroresonance while FACTS are Switch off	105
Figure 4.46	Compare 1 <sup>st</sup> harmonic of FACTS devices and Ferroresonance while FACTS are Switch on	107
Figure 4.47	Compare 1 <sup>st</sup> harmonic of FACTS devices and Ferroresonance while FACTS are Switch off	107
Figure 4.48	Compare 2 <sup>nd</sup> harmonic of FACTS devices and Ferroresonance while FACTS are Switch on	109
Figure 4.49	Compare 2 <sup>nd</sup> harmonic of FACTS devices and Ferroresonance while FACTS are Switch off	110
Figure 4.50	Compare 3 <sup>rd</sup> harmonic of FACTS devices and Ferroresonance while FACTS are Switch on	111
Figure 4.51	Compare 3 <sup>rd</sup> harmonic of FACTS devices and Ferroresonance while FACTS are Switch off	112

## LIST OF SYMBOLS

$C_d$	-	Grading Capacitance
$C_w$	-	Winding Capacitance
$C_m$	-	Line to line Capacitance
$C_g$	-	Line to ground Capacitance
$C_s$	-	Coupling Capacitance
$R_m$ (v)	-	Transformer Core Losses
$L_m$ ( $\varphi$ )	-	Nonlinear Inductance
$X_L$	-	Impedance of Inductor
$X_C$	-	Impedance of Capacitor
$L_{sat}$	-	Non-linear Inductor Saturation
$h_C$	-	Coercive Magnetic Field
$h_m$	-	Last Return Point of the Magnetic Field
$M_{rev}$	-	Reversible Component of Magnetizing
$M_{irr}$	-	irreversible Component of Magnetizing
$M_{an}$	-	Anhysteretic Curve
$M_s$	-	Saturation Magnetizing
$H_e$	-	External applied Field
$\alpha$	-	Molecular field parameter



# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 Project Background**

Ferroresonance phenomenon occurs in electrical circuits which are consisting of magnetizing cores, such as in the transmission and distribution network.

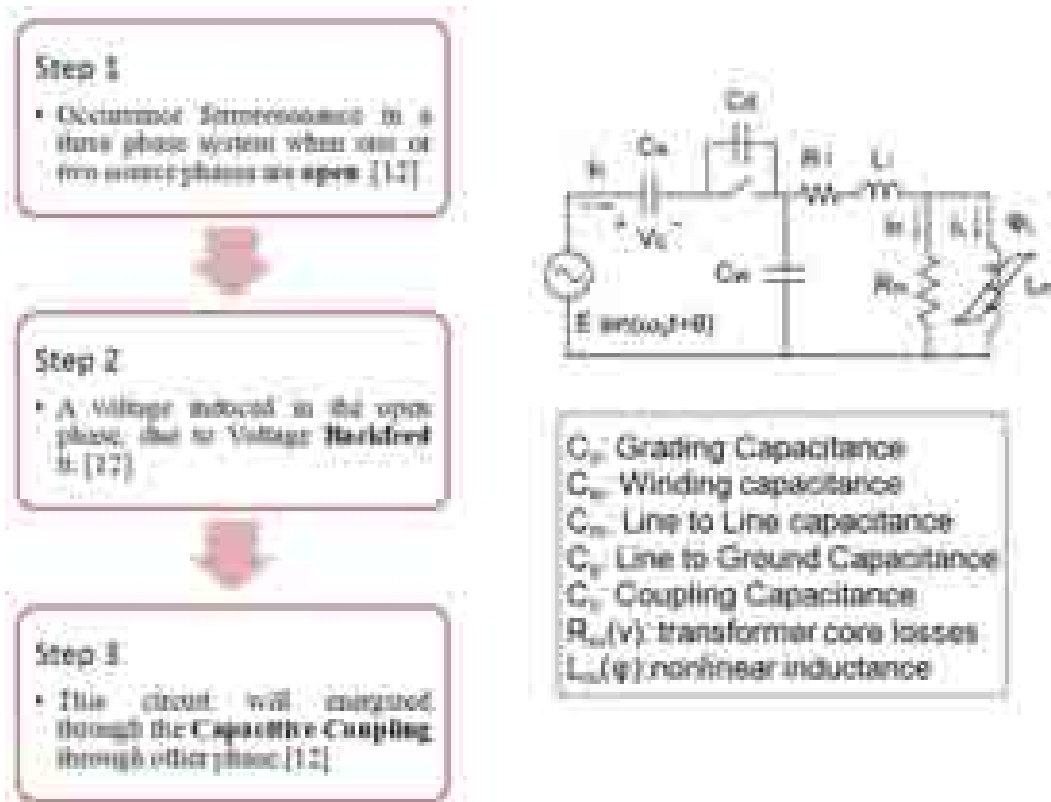
Transformers often operate close to the knee point of magnetizing curve under normal condition. Therefore any sudden change in voltage or current can change the operation point on the magnetizing curve and saturation may result.

This phenomenon is reflected in the change of the equivalent nonlinear reactance of the transformer. Now, if the value of the saturated reactance reaches a value such that it causes resonance with the equivalent capacitance of the network, then an over current or over voltage may occur.

Transformers, electrical motor, reactors and generators are examples of equipment having magnetizing cores.

Possible causes of ferroresonance occurrence are:

- i. Switching operations
- ii. Faults (specially SLG)
- iii. Lightning surges
- iv. Ferranti effects



**Figure1.1:** Steps of formation of ferroresonance and coupling capacitance

## 1.2 Problem Statement

Although some techniques had been applied to mitigate ferroresonance on capacitive VTs, methods to mitigate ferroresonance on power transformers are almost not studied or reported. This project simulates circuit models of ferroresonance based on two mitigation techniques so as to reduce or prevent damages due to ferroresonance.

### **1.3 Objectives**

- To identify ferroresonance phenomenon and its models
- To model ferroresonance by applying ATP.
- To model and analyze the UPFC and STATCOM effect on mitigation of ferroresonance.

### **1.4 Scope of Project**

The main scope of this project is to model ferroresonance phenomenon at transmission network, due to single line switching. Nonlinear inductor of power transformer resonates with coupling capacitance and cause ferroresonance. Therefore, the current in the opened phase bounce up and highly distorted. Because of the FACTS device connection and its switching time control, the network topology changes. Thus over current and over voltage are therefore damped by the application of the UPFC and STATCOM.

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